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<b>(54) Title:</b> IMPROVED DEPILATORY METHOD AND DEVICE			
<b>(57) Abstract</b> <p>An improved method of hair removal, and associated devices. For the removal of shallow and/or light-colored hair, the targeted skin region is irradiated with light of a wavelength between 550 nm and 680 nm, and an energy density of between 30 J/cm<sup>2</sup> and 100 J/cm<sup>2</sup>, for between 1 ms and 100 ms. A targeted area about as wide as the depth of the hair follicles to be destroyed is irradiated using one or more sources, such as lasers, that produce considerably narrower beams, either by scanning one beam across the target or by irradiating the target using several beams simultaneously.</p>			

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## APPLICATION FOR PATENT

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Title: IMPROVED DEPILATORY METHOD AND DEVICE

10 FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to hair removal and, more particularly, to an improved method and device for permanently removing hair using pulses of light.

The use of intense light to heat hairs, and the follicles whence they grow, to temperatures high enough to kill the follicles without appreciable damage to the surrounding tissue, is known. Tankovich, in US Patent No. 5,226,907, teaches a method of hair removal in which the portion of the hair below skin level is coated with a substance such as carbon that absorbs light of selected frequencies (10.6 micron infrared light in the preferred embodiment) than the surrounding tissue. Anderson et al., in US Patent No. 5,595,568, which is incorporated by reference for all purposes as if fully set forth herein, relies on the natural pigmentation of the hair to absorb light in a range of 680 nm to 1200 nm.

With the object of destroying many follicles at once, both Tankovich and Anderson et al. direct a light beam at least on the order of 1 cm wide at each area of skin to be treated. As noted by Anderson et al., the width of the light beam preferably is at least as great as the depth of the follicles to be destroyed. Depending on their specific location, follicles may be between 0.1 mm and 0.5 mm deep. The energy density of the light beam taught by Anderson et al. is between 10 J/cm<sup>2</sup> and 200 J/cm<sup>2</sup>, most preferably between 30 J/cm<sup>2</sup> and 50 J/cm<sup>2</sup>. Although lasers are readily available that produce beams of coherent light with this width and energy density, it would be advantageous to be able to use less expensive diode lasers, with beam widths as small as 0.05 mm, for this application.

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Figure 1 is a plot of the penetration depth of light in skin tissue, as a function of wavelength. Light in the wavelength range taught by Anderson et al., 680 nm to 1200 nm, penetrates skin tissue to depths of 2 mm or greater. Thus, a larger volume of skin tissue is heated than is strictly necessary when destroying follicles shallower than 2 mm, and there is  
5 a risk of overheating the surrounding skin tissue.

#### SUMMARY OF THE INVENTION

According to the present invention there is provided an improved method for removing hairs from a skin region of a patient, including the step of irradiating the skin  
10 region with light of a first wavelength shorter than about 680 nm.

According to the present invention there is provided an improved method for removing multiple hairs from a skin region of a patient, each of the hairs being in a corresponding follicle at a certain depth in the skin region, including the step of irradiating a plurality of spots in a portion of the skin region having a lateral extent at least as great as the  
15 depth of the follicles, so as to deposit at least about  $30 \text{ J/cm}^2$  of energy in the portion of the skin region within a time shorter than about 200 ms.

According to the present invention there is provided a device for sequentially irradiating a plurality of substantially contiguous spots in a two-dimensional pattern on a target, including: (a) a source of light; and (b) a mechanism for sequentially directing the  
20 light at each of the spots in the pattern.

According to the present invention there is provided a device for simultaneously irradiating a plurality of substantially contiguous spots in a two-dimensional pattern on a target, including: (a) an array of apertures congruent with the pattern; (b) at least one light source; and (c) a mechanism for optically coupling the at least one light source with the  
25 apertures.

Figure 2 shows experimentally measured absorption coefficients of hair of four different colors, as a function of wavelength. In the especially preferred wavelength range of Anderson et al., 800 nm - 900 nm, the absorption coefficient of dark (black, red or brown) hair is between about  $50 \text{ cm}^{-1}$  and about  $70 \text{ cm}^{-1}$ , but the absorption coefficient of blond hair is only about  $25 \text{ cm}^{-1}$ . To obtain, for blond hair, the light absorption obtained in dark hair by the method of Anderson et al., it is necessary to use light in the wavelength range of the present invention, 550 nm to 680 nm. Thus, the wavelength range of the present invention is preferred over the prior art wavelength range, both for shallow hair and for blond hair. Light in the wavelength range of the present invention may be supplemented by light in the prior art wavelength range for removing shallow dark hair. The preferred energy density and pulse length are similar to those of the prior art: an energy density between about  $30 \text{ J/cm}^2$  and about  $100 \text{ J/cm}^2$ , and a pulse length between about 1 ms and about 100 ms. The upper end of this time span is the maximum expected thermal relaxation time of a hair follicle enclosed in dermal fat.

In the second aspect of the present invention, the therapeutic beams of light are created by diode lasers, or similar sources, that produce collimated beams of light that are narrower than the desired depth of penetration. To achieve the desired effective beamwidth, the beam or beams are directed at multiple spots within a region of skin whose lateral extent is as great as the desired depth of penetration. One beam may be directed sequentially at several spots within the region, or several beams may be directed simultaneously at the several spots within the region, as long as the desired energy density of at least about  $30 \text{ J/cm}^2$  is deposited within the desired time of no more than about 200 ms.

The preferred range of spot diameters within the scope of the present invention is between about 0.5 mm and about 5 mm. A spot as small as 0.5 mm in diameter may require an energy density as high as about  $1000 \text{ J/cm}^2$ .

The scope of the present invention also includes devices for effecting this irradiation with an effective beamwidth wider than the collimated beam produced by the light source. In one embodiment of the device, a diode laser is optically coupled to a proximal end of an optical waveguide that is about as wide as the collimated beam produced by the laser, and the 5 other, distal end of the waveguide is scanned across the target region. In another embodiment, several diode lasers are optically coupled to the proximal ends of several optical waveguides, and the distal ends of the waveguides are bundled in a two dimensional pattern that is as wide as the desired effective beamwidth. Most preferably, the distal ends of the waveguides are inserted in a spacer which, when held against the target, holds the distal 10 ends of the waveguide stationary with respect to the target and at a fixed distance from the target.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the 15 accompanying drawings, wherein:

FIG. 1 is a graph showing the penetration depth of light of various wavelengths in skin tissue;

FIG. 2 is a graph showing the absorption coefficient of hair of various colors as a function of wavelength;

20 FIG. 3 shows an irradiation pattern of the present invention superposed on a prior art irradiation pattern;

FIG. 4 is a schematic depiction, partly in perspective, of a first device of the present invention;

25 FIG. 5 is a schematic depiction, partly in perspective, of a second device of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of a method and device which can be used to remove unwanted hair.

5 The principles and operation of depilation according to the present invention may be better understood with reference to the drawings and the accompanying description.

Referring now to the drawings, Figure 3 shows a square 10 that is 3 mm on a side. Superimposed thereon is a pattern of 16 partly overlapping circles 12, each 1 mm in diameter, for the equivalent irradiation of a skin region according to the present invention.

10 To deposit  $30 \text{ J/cm}^2$  of light energy in the area of square 10 within 75 msec requires a 36W laser. To deposit the same  $30 \text{ J/cm}^2$  sequentially in circles 12 within 75 msec (4.7 msec per circle) requires a 50W laser. To deposit the same  $30 \text{ J/cm}^2$  simultaneously in circles 12 within 75 msec requires 16 3W lasers.

Figure 4 shows, schematically, a device 20 for effecting the sequential irradiation of 15 circles 12. The mechanical portion of device 20 is based on a rigid hollow rectangular frame 22. Rising from three of the corners of frame 22 are three towers 24, 26 and 28. Tower 24 supports a stepping motor 36 which rotates a mirror 30 about a vertical rotation axis. From tower 26 projects an arm 34 which supports a second stepping motor 38. Stepping motor 38 rotates a mirror 32 about a horizontal rotation axis. Tower 28 supports a clamp 40 which 20 secures a distal end 46 of an optical waveguide 44 to tower 28 so that distal end 46 of optical waveguide 44 points at mirror 30. Waveguide 44 is circular in cross section and 1 mm in diameter. The combined rotations of mirror 30 in a horizontal plane and mirror 32 in a vertical plane directs light emerging from distal end 46 of optical waveguide 44 to any desired lateral position within the interior of frame 22.

A proximal end 48 of waveguide 44 is optically coupled to a laser 50 having an output power of 50W. Laser 50 is energized and controlled by a microprocessor-based control system 52 via a power/control line 54. Stepping motors 36 and 38 are energized and controlled by control system 52 via a power/control line 56.

5 To use device 20, frame 22 is positioned to enclose the targeted skin region. Control system 52 then sequentially rotates mirrors 30 and 32 to direct the light emerging from distal end 46 to each of circles 12 in the pattern of Figure 3, spending 4.7 msec at each circle 12 while firing laser 50. Distal end 46 functions in combination with mirrors 30 and 32 as an optical aperture, wherefrom light from laser 50 emerges to irradiate the target. Laser 50 may  
10 be pulsed, with the pulses thereof synchronized with the rotations of mirrors 30 and 32 so that the pulses are directed at each of circles 12. Alternatively, laser 50 may operate continuously, with mirrors 30 and 32 providing a dwell time of 4.7 msec at each of circles 12.

Figure 5 is a partial schematic depiction of a device 60 for effecting the simultaneous  
15 irradiation of circles 12. 16 fiber optic waveguides 64, each of circular cross section and 1 mm in diameter, are arranged in a bundle 62 so that distal ends 66 of waveguides 64 are deployed in the pattern of circles 12 of Figure 3. Distal ends 66 of waveguides 64 are inserted together in a proximal end 74 of a hollow rectangular sleeve 70. When a distal end 76 of sleeve 70 is placed adjacent to a targeted skin region, sleeve 70 keeps distal ends 66 of  
20 waveguides 64 at the desired distance from the target. A proximal end 68 of each waveguide 64 is optically coupled to a separate 3W diode laser 72. With sleeve 70 in place above the target, lasers 72 are fired simultaneously for 75 msec. Distal ends 66 serve as apertures, wherefrom light from lasers 72 emerges to irradiate the target.

25 Diode lasers suitable for implementing the various aspects of the present invention are manufactured by a variety of manufacturers, for example Applied Optronics Corporation.

While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.

## WHAT IS CLAIMED IS:

1. An improved method for removing hairs from a skin region of a patient, comprising the step of irradiating the skin region with light of a first wavelength shorter than about 680 nm.
2. The method of claim 1, wherein said first wavelengths longer than about 550 nm.
3. The method of claim 1, further comprising the step of irradiating the skin region with light of a second wavelength longer than about 680 nm.
4. The method of claim 1, wherein said light has an energy density, on said skin region, of between about 30 J/cm<sup>2</sup> and about 1000 J/cm<sup>2</sup>.
5. The method of claim 1, wherein said light is directed at the skin region in at least one pulse having a duration of between about 1 ms and about 200 ms.
6. An improved method for removing multiple hairs from a skin region of a patient, each of the hairs being in a corresponding follicle at a certain depth in the skin region, comprising the step of irradiating a plurality of spots in a portion of the skin region having a lateral extent at least as great as the depth of the follicles, so as to deposit at least about 30 J/cm<sup>2</sup> of energy in said portion of the skin region within a time shorter than about 200 ms.

7. The method of claim 6, wherein each of said plurality of spots has a diameter between about 0.5 mm and about 5 mm.

8. The method of claim 6, wherein said irradiating is effected using light having a wavelength between about 550 nm and about 680 nm.

9. The method of claim 6, wherein said irradiating is effected using light having a wavelength between about 680 nm and about 1000 nm.

10. The method of claim 6, wherein said irradiating of said plurality of spots is effected substantially simultaneously.

11. The method of claim 6, wherein said irradiating of said plurality of spots is effected sequentially.

12. A device for sequentially irradiating a plurality of substantially contiguous spots in a two-dimensional pattern on a target, comprising:

- (a) a source of light; and
- (b) a mechanism for sequentially directing said light at each of the spots in the pattern.

13. The device of claim 12, wherein said mechanism includes an aperture wherefrom said light emerges to strike the target.

10

14. The device of claim 13, wherein said mechanism includes:
  - (i) an optical waveguide having a proximal end and a distal end, said proximal end being optically coupled to said source of said light, said aperture including said distal end, and
  - (ii) a mechanism for scanning said distal end across said pattern.

15. A device for simultaneously irradiating a plurality of substantially contiguous spots in a two-dimensional pattern on a target, comprising:

- (a) an array of apertures congruent with said pattern;
- (b) at least one light source; and
- (c) a mechanism for optically coupling said at least one light source with said apertures.

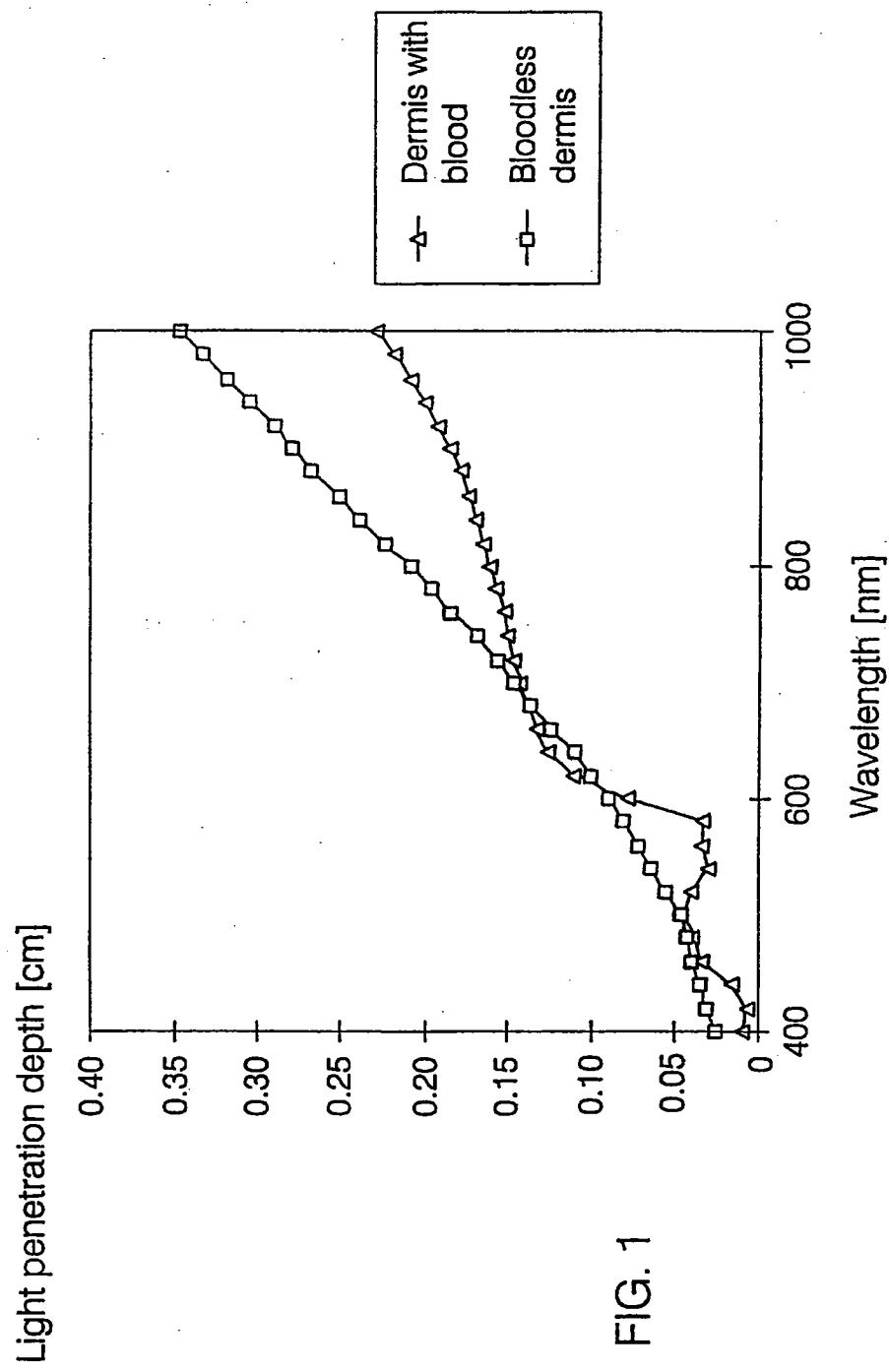
16. The device of claim 15, wherein said mechanism includes a plurality of optical waveguides, each of said optical waveguides having a proximal end and a distal end, each of said proximal ends being optically coupled to one of said at least one light source, each of said apertures including one of said distal ends.

17. The device of claim 16, including a plurality of said at least one light source, wherein each of said optical waveguides is optically coupled to a separate one of said plurality of light sources.

18. The device of claim 15, further comprising:

- (d) a spacer for holding said apertures at fixed position relative to the target.

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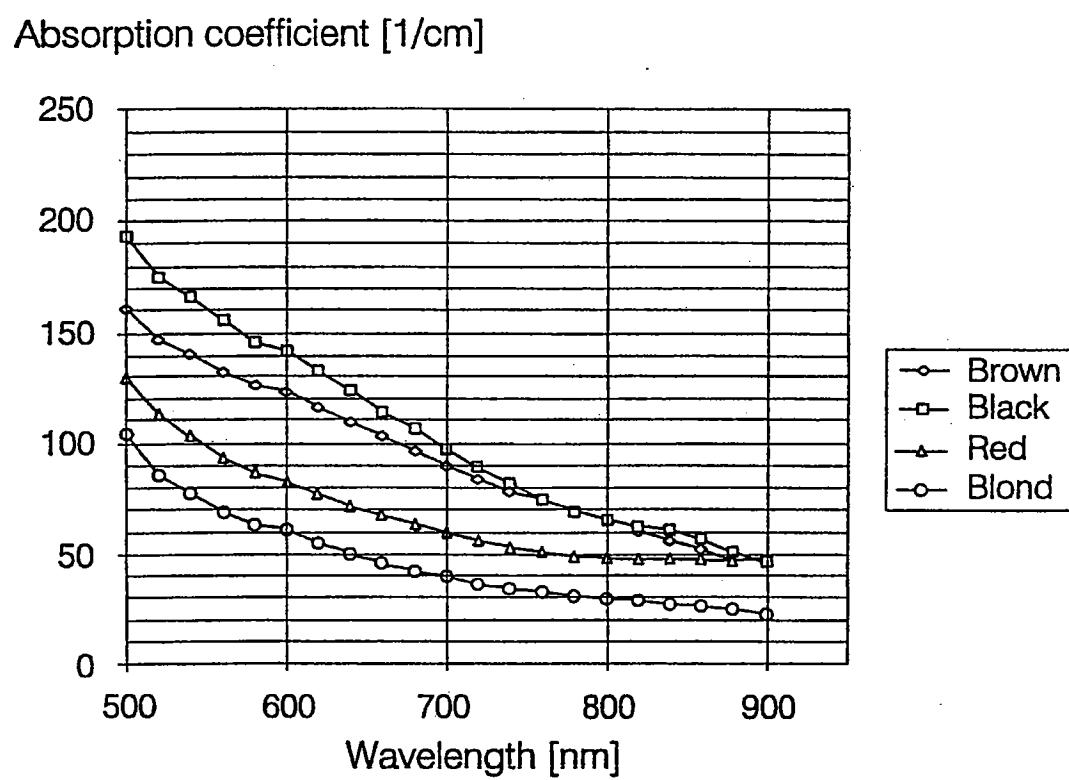


FIG. 2

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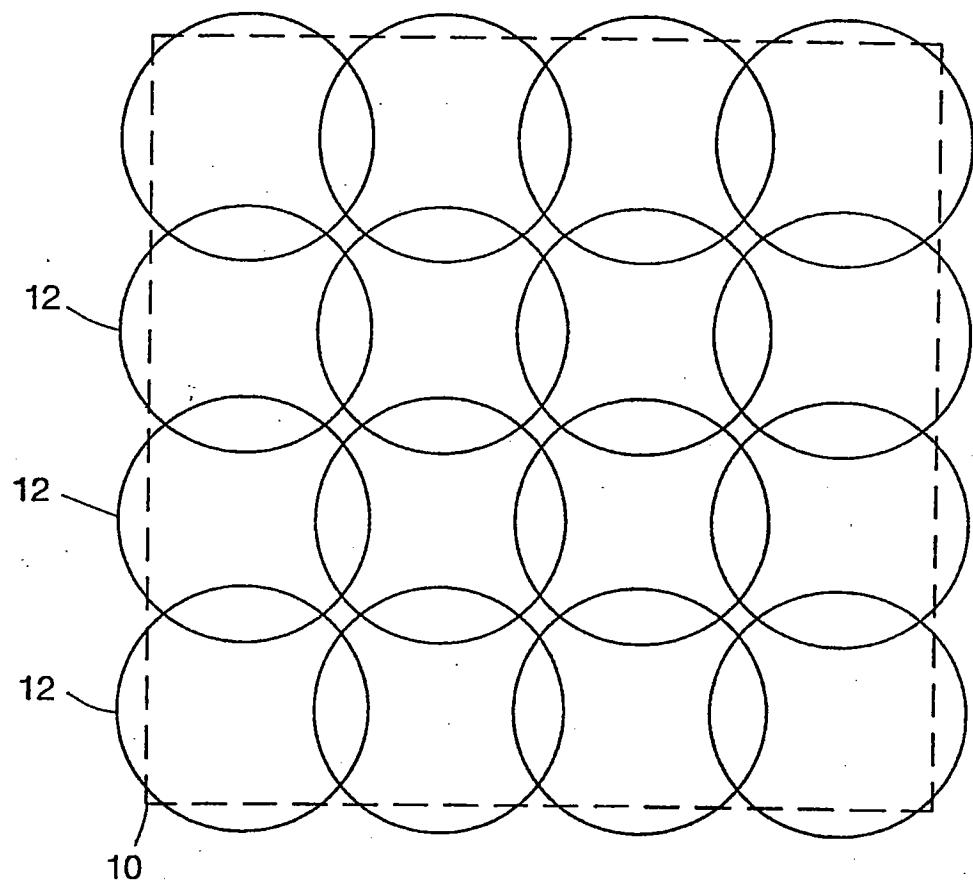


FIG. 3

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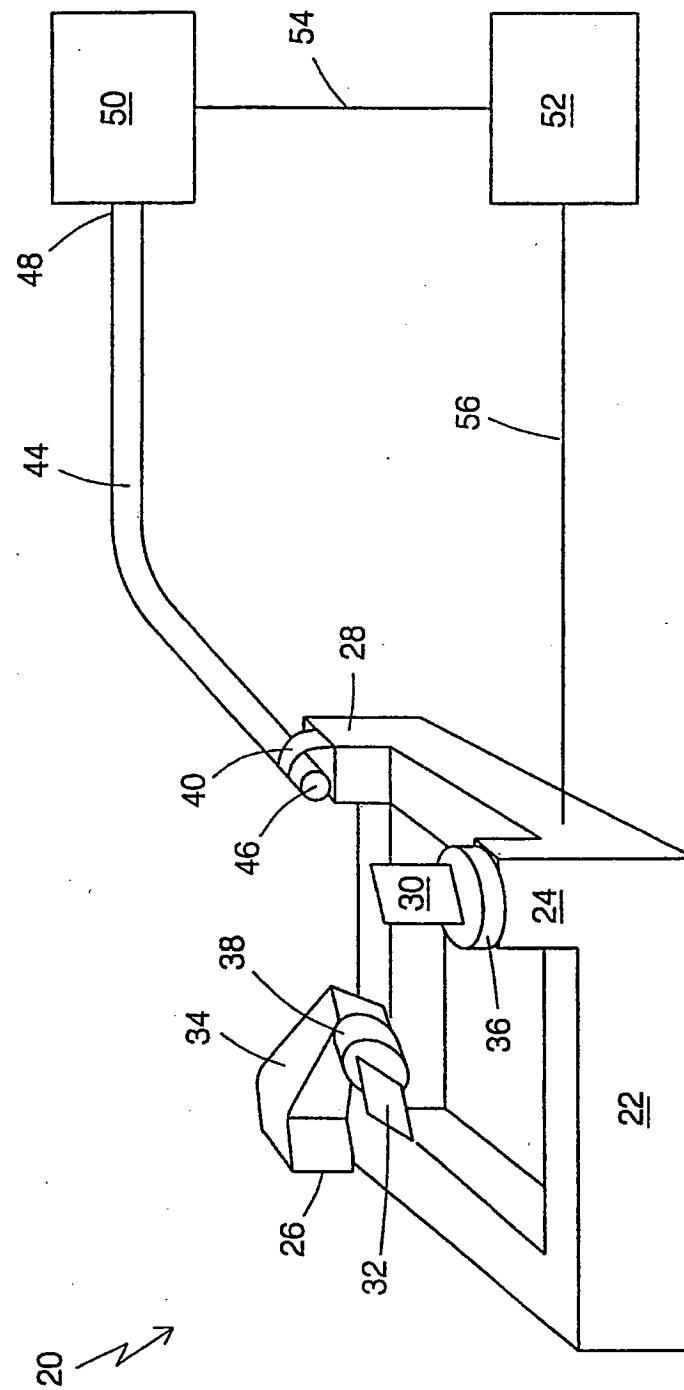
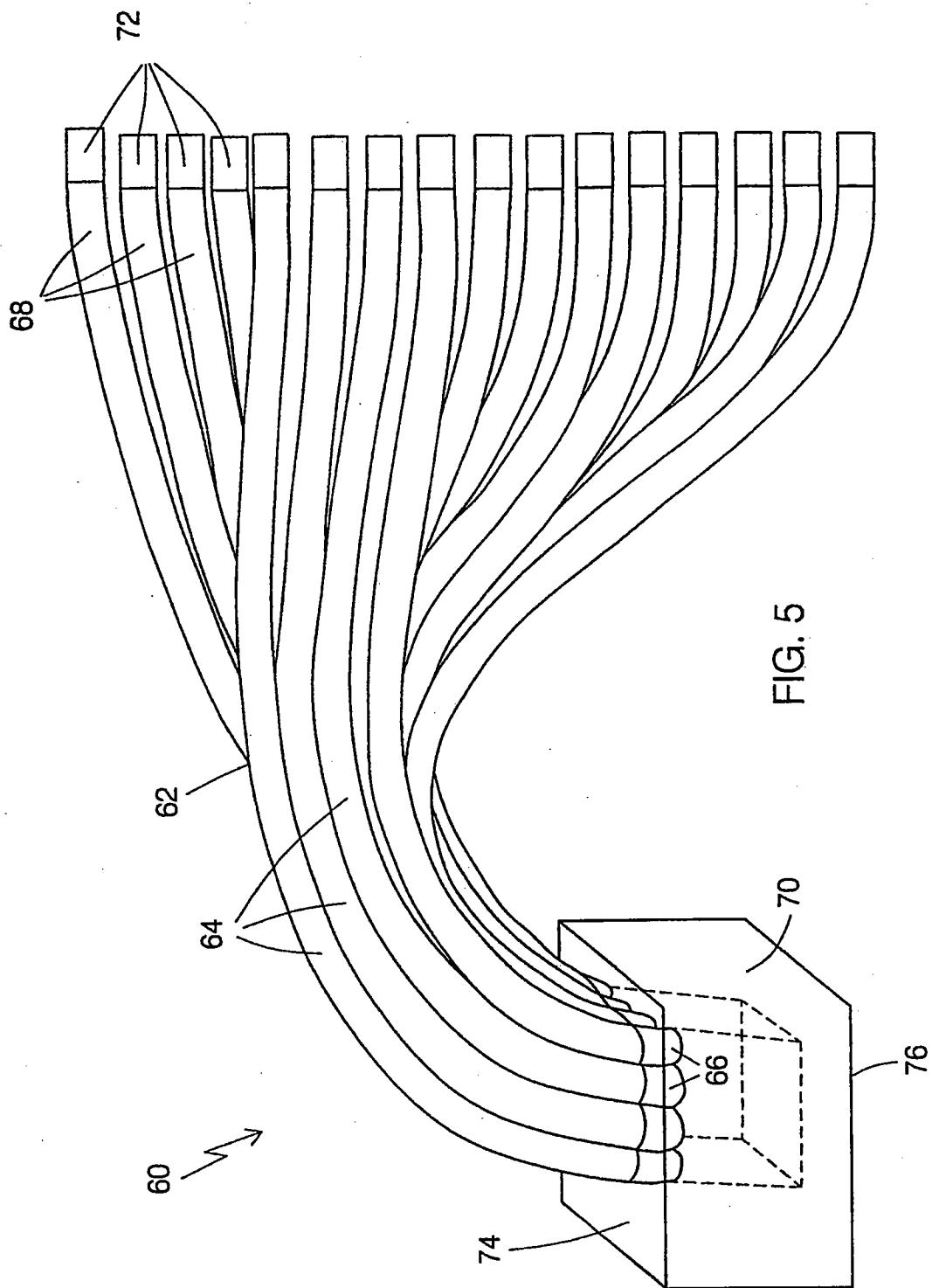


FIG. 4

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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US98/25412

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61N 5/02

US CL :606/9

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 606/3-18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,182,857 A (SIMON) 02 February 1993, entire document.	1-13
Y		14-18

Further documents are listed in the continuation of Box C.

See patent family annex.

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